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DEPARTMENT OF COMMERCE - BUREAU OF MINES

EFFECT ON WORKERS OF AIR CONDITIONS[1]

By R. R. Sayers[2]

That the maintenance of proper air conditions is a most important factor in the control of occupational hazards is shown by the large amount of material presented each year through the technical journals on the effects on workers of injurious dusts, gases, and variations in temperature and humidity.

SUMMARY OF RECENT LITERATURE ON EFFECTS ON WORKERS OF EXPOSURE TO DUSTS

The subject of the control of dust and dust diseases continues to be a matter of serious concern in most of the industrial countries of the world, as indicated by the following summary of reports published in a number of foreign countries as well as in the United States.

Australia.- The Workmen's Compensation Act of 1920 for New South Wales[3] provided for the promulgation of schemes for the compensation of workers disabled by silica or other dust. In 1924 the prevalence of silicosis and tuberculosis among Sydney stonemasons, quarrymen, sewer miners and rockchoppers was investigated by a Technical Committee of Inquiry, appointed upon the recommendation of the New South Wales Board of Trade. The findings of this committee were published by the Government in 1925. No scheme was promulgated by the Government and in 1926 the Act was amended limiting its scope to workmen disabled by disease caused by silica-dust. This was promulgated and gazetted on September 16, 1927, and applies to men working in sandstone as stonemasons, quarrymen, rockchoppers, and sewer miners in the County of Cumberland.

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[1] Report of the Chairman of the Subcommittee on Physiological Factors of the Committee on Ventilation of the American Institute of Mining and Metallurgical Engineers presented at the meeting in New York City, February, 1931. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6439."

[2] Chief surgeon, U. S. Bureau of Mines or, chief, health and safety branch; surgeon, U. S. Public Health Service.

[3] Third Annual Report and Statistics of the Workers' Compensation Commission of New South Wales for the Year July 1, 1928, to June 30, 1929; Published December 18, 1929, 78 pp.

The report of the Workers' Compensation Commission[4] gives information in regard to 1,300 of 1,500 workmen examined up to August 23, 1929. Of 107 stonemasons examined, 9 had tuberculosis, 17 were in various stages of silicosis, and 26 had silicosis with tuberculosis. These men had worked in the industry for periods varying in length from 10 to 55 years. Of the 29 monumental masons, 2 had tuberculosis, 1 had Class A silicosis, and 5 had silicosis with tuberculosis. No statement is given as to the length of time worked by these men, with the exception that the one suffering from Class A silicosis had worked for 31 years in the industry. Of the 37 ballast quarrymen, 1 had tuberculosis and 2 had marked silicosis. The two with marked silicosis had worked 2 and 12 years respectively, but no statement is made in regard to the one man with tuberculosis. Of the 80 dimension quarrymen, 6 were diagnosed as having tuberculosis, 3 as having early silicosis, 2 as having marked silicosis, and 16 as having silicosis with tuberculosis. The three cases diagnosed as in the early stage of silicosis had worked 18, 20, and 20 years, respectively, and those with marked silicosis had worked 16 and 20 years, respectively. Among the 377 rockchoppers examined, 12 had tuberculosis, 25 had silicosis, and 10 had silicosis with tuberculosis. These men had worked in the industry for periods varying from 5 to 32 years.

Workmen in the Broken Hill mines are compensated under a scheme contained in the Workmen's Compensation (Broken Hill) Act, 1920-1927. The Broken Hill (Pneumoconiosis-Tuberculosis) Compensation Scheme is administered by a joint committee at Broken Hill.[5]

In regard to conditions at Broken Hill, according to George,[6] up to June 30, 1929, in no case has a man with no mining experience before 1921, and who has worked in Broken Hill only during the succeeding years, been discovered with dust disease of the lungs. This means that at Broken Hill, as far as is known, the period of exposure is at least eight years, and the appearance of the first case of pneumoconiosis among men in this classification is still awaited.

The idea that two factors operate in the development of pneumoconiosis in a miner is considered by George as probably the most important development during the past few years toward an understanding of the true nature of dust disease of the lungs. He states that the following observations made at Broken Hill during the past eight years support the view that there is a tubercular element in every case of dust disease, even in so-called "simple" pneumoconiosis:

> The fact that of many men exposed at work to exactly similar conditions only a percentage are affected by dust, i.e., there must be an additional factor in the man himself for the production of the disease.

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[4] See footnote 3.

[5] See footnote 3.

[6] George, W. E., Eight Years' Further Observation of Dust Disease of the Lungs Occurring Amongst Miners at Broken Hill: Third Annual Report and Statistics of the Workers' Compensation Commission of New South Wales for the Year July 1, 1928, to June 30, 1929, Dec. 18, 1929, 78 pp.

The large percentage of men with "simple" pneumoconiosis who have eventually developed "overt" tuberculosis, even when removed to surroundings where it was most unlikely they would be reinfected by the tubercle bacillus. This is particularly emphasized by the after histories of certain Broken Hill miners (34 in number), suffering from simple pneumoconiosis, who took up blocks on the Murrumbidgee Irrigation Area at Griffith, New South Wales. These men cleared virgin country, erected new homes, and lived in the most healthy surroundings possible, but 12 of them have since developed overt tuberculosis, and 7 of the 12 have died of pulmonary tuberculosis. These men, far from Broken Hill, were not in contact with beneficiaries who had tuberculosis, and who may have been accused of bestowing the tubercular infection.

In most radiographs, even of so-called "simple" pneumoconiosis, an area suspicious of either healed or incipient tuberculosis can be recognized if searched for. Gradually improved radiographic technique has made the recognition of this area much more frequent than was the case eight years ago. When watched over a period of years, this suspicious area has frequently been observed extending, and eventually the condition of pneumoconiosis with tuberculosis is established clinically as well as radiographically. In cases which have suddenly developed an acute tuberculosis after showing no change for years an area such as this has been observed to be the starting point of the active disease.

Chapman[7] has the following to say in this connection:

> In the production of silicosis it would thus appear that the particles of silica are in many individuals absorbed in the lungs without giving rise to silicosis. In other individuals the particles of silica do not appear to be absorbed, but give rise to inflammatory areas starting silicosis of the lungs. It has been suggested that this inflammatory process occurs in persons already the subjects of tubercular inflammation. It is said that it is the tuberculous subjects who become silicotic. The question may be asked whether the areas of the lungs in which particles of silica are not removed and in which silicosis develops are not already the seats of tuberculous processes. The answer would, however, appear to be in the negative since the characteristic feature of the silicotic inflammatory change is its uniform distribution throughout the lungs; even at an early stage, uniformity of distribution in the pathological process is characteristic of silicosis. On the other hand, it is unusual to observe uniformity of distribution throughout the lungs in the early tubercular inflammations. My friend, Dr. S. A. Smith, reminds me that early tuberculosis tends to attack the apices of the lungs. Many have observed that the apices tend to be the last areas attacked by silicotic inflammation.

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[7] Chapman, H. G., Silicosis and Tuberculosis. Third Annual Report and Statistics of the Workers' Compensation Commission of New South Wales for the Year July 1, 1928, to June 30, 1929, Dec. 18, 1929, 78 pp.

England.- Bridge,[8] in calling attention to the importance of silicosis as an industrial disease, says that while to Collis belongs the credit of drawing attention to the effects of the inhalation of occupational dust containing free silica, even he did not visualize the widespread nature of the industries in which dust containing free silica occurs, as indicated by the recent plan for compensation under the Various Industries (Silicosis) Scheme, which covers such widely different industries as the manufacture of pottery, the making of scouring powders containing silica flour, the sandblasting of castings, the making of poultry grit by grinding and crushing of flints, the mining of tin and coal, and the making of vitreous enamels, as well as the sandstone industry affecting quarriers and masons.

One of the points emphasized by Bridge is that there are few, if any, dusts occurring in industry that will not produce, in certain individuals, an inflammatory condition of the skin; but that however distressing and economically wasteful simple lesions of the skin by practically all dusts may be, they are as nothing compared with cancer of the skin produced by dust. He states that although the main incidence occurs among the patent fuel workers in South Wales, the pitch workers in gas works, the loaders and unloaders of pitch, and the workers exposed to pitch dust in tar distilleries, all workers wherever they may be share the risk.

According to The Colliery Guardian,[9] a subject of increasing importance to the mining community is the occurrence of cases of silicosis in coal mines. Birmingham University hopes shortly to commence systematic chemical investigation of the shales in the vicinity of coal seams and those in which drilling and blasting have frequently to be done. It is also proposed to investigate the quantity and nature of the dust suspended in the air in underground places where drilling is being carried out.

It is the understanding of The Colliery Guardian[10] that the Home Office proposes to make certain alterations in the Various Industries (Silicosis) Scheme, 1928, that may especially affect coal miners. It was this scheme that the British Medical Journal characterized as an example of the unusual course taken by the Government of legislating first and postponing inquiry until a later date. The same paper emphasized the necessity for some standard of what constitutes an injurious amount of silica-dust. Not long ago the Trades' Union Council,[11] on behalf of the Miners' Federation, made representations to the Home Secretary that great hardship was being caused to workmen, especially in coal mines, by reason of the words "or any rock containing less than 50 per cent free silica" in the definition of silica rock in the scheme. These words were specifically inserted on the advice of the Geological Survey for the purpose of excluding the granite industry, pending further medical inquiry into the occurrence of silicosis in that industry. That inquiry, which has now been completed, found that silicosis in the granite industry is confined to certain occupations and, therefore, it is held that the reason for the adoption of the reduction as to 50 per cent has disappeared. The chief complaint of the Miners' Federation was that a heavy burden was imposed upon the miner by the requirement that he must prove that he had, within the previous three years, been drilling or handling one of the classes of stone included in the definition of "silica rock."

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[8] Bridge, J. C., Remarks on Occupational Dust: British Medical Jour., No. 3598, December 21, 1929, pp. 1143-1147.

[9] The Colliery Guardian, Mining Research at Birmingham University: Vol. 141, No. 3638, July 11, 1930, pp. 155-157.

[10] The Colliery Guardian, Silicosis in Coal Mines: Vol. 141, No. 3633, August 15, 1930, pp. 591-592.

[11] Ibid.

The Colliery Guardian considers that the main difficulty arising from the amended scheme will be in adjudicating upon claims by workmen who suggest that they have contracted silicosis through working in or traveling in roadways where stone-dust is used in accordance with the regulations to prevent coal-dust explosions. It is now provided that no dust shall be used for this purpose that may be prohibited by the Board on the ground that it would be injurious to the health of persons working in the mine. It is not thought that this regulation will prevent claims from being put forward by workmen, who may suggest that the contraction of phthisis is in itself the best proof that the dust employed is of a dangerous character.

The Workmen's Compensation Act, 1925, was extended to industries involving exposure to asbestos-dust, as a result of the report of an inquiry submitted to Parliament in March, 1930,[12] which stated that there was grave danger of workers in the asbestos industry contracting fibrosis of the lungs, culminating not merely in disablement but in death. Fourteen deaths were recorded and the disease affected one in eight of those employed, a figure that only applied to those who were actually in employment at the time the examination took place - roughly 2,000 people. The employers, who believed that the provisions of this bill were on the right lines, and the Trade Union Congress representing the industries and workers concerned, were also agreed.[13]

The Lancet[14] calls attention to the difference in the fibrosis resulting from asbestos-dust and that from silica-dust encountered in gold mines. The whorled formations seen in gold miners' phthisis are absent and are replaced by a diffuse fine interstitial pneumonia. The difference is also reflected in radiograms of the two conditions, the gold-miner's lung showing scattered dense rounded opacities which contrast with the fine basal mottling and linear striae which are characteristic of the asbestos-worker's lung. A peculiar feature of pulmonary asbestosis is the presence of the so-called asbestosis bodies. These were discovered by Prof. Matthew Stewart in the sputum of workers suffering from the disease; they have been demonstrated by a number of investigators in sections from the lungs and in lung juice removed during life by exploratory puncture or expressed at autopsy. The asbestosis body, which bears a curious resemblance to a minute crustacean, consists of a central core of asbestos fiber which appears to be embedded in a series of disks. One end of the fiber is often buried in a bulbous extremity, and this with the succeeding disks produces the appearance of a minute screw. The nature of the aggregation around the central spicule is unknown, but Gloyne has been able to demonstrate the central fiber by exposing the containing body to the action of sulphuric acid.

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[12] Merewether, E. R. A., and Price, C. W.; Report on Effects of Asbestos Dust on the Lungs: Home Office, London, 1930, 34 pp.

[13] The Lancet, Workmen's Compensation (Silicosis Bill): Vol. 2, No. 3, July 19, 1930, p. 163.

[14] The Lancet, Pulmonary Asbestosis: Vol. 50, No. 13, March 29, 1930, pp. 701-702.

France.- The interest in France in the subject of the health hazard from dust is shown by the decree, issued by the French Ministry of Labor in November, 1929, which obliges doctors to make notification of pulmonary affections caused by dusts of silica, lime, clay, or coal, in order to obtain information upon which to base an extension of compensation for disease. Feil[15] is of the opinion that the decree should be modified to require notification of silicosis only, since other dusts, such as coal, iron, or clay, are injurious only when associated with free silica, which causes silicosis when inhaled.

Germany.- German investigators[16] consider occupational dust to be extraordinarily significant for industrial hygiene and to continue to-day to take first place among the causes of occupational diseases, especially tuberculosis of the lungs. Jötten-Münster[17] says that it is an outstanding fact, known for many years and from many statistics, that workers engaged in dusty trades have a larger death rate for tuberculosis of the lungs than other workers. He calls attention to the fact that the metal grinders in Solingen and Sheffield always die of phthisis at an age before their children are grown. In the Solingen district, for example, the death rate is double that of the rest of the population and the illness figure is four or five times higher. The file cutters and grinders show the highest mortality from tuberculosis. The workers in the metal mines do not have as many fatalities from dust-lung tuberculosis. In 1920, Ickert found a tuberculosis mortality rate of 19.5 per 10,000 among the bituminous marl-slate miners of the Mansfield mountain district where some years later Redeker found the rate to be 36.5 per 10,000 miners. As is well known, with stoneworkers four-fifths of all cases of death can be traced back to tuberculosis. This is especially true for the sandstone and flint workers, as well as for those who work in ceramic factories. Those who work in granite are somewhat less endangered, since it contains less crystalline SiO_2 than sandstone which consists principally of silica.

Jötten-Münster[18] describes the investigations carried out by the Government Research Division, of the Institute of Hygiene, University of Münster, Bochum, Germany, as follows:

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[15] Feil, A., Contribution a l'étude des pneumokonioses professionnelles: Presse Médicale, No. 56, July 12, 1930, pp. 939-942.

[16] Die gewerbliche Staublungenerkrankung: Beihefte Zentralb. Gewerbeh. Unfallverhütung, No. 15, pub. by Julius Springer, 1929, 146 pages.

[17] Jötten-Münster, K. W., Staublünge und Staublungentuberkulose: Beihefte Zeutralb. Gewerbeh, Unfallverhütung, No. 15, pub. by Julius Springer, 1929, pp. 22-49.

[18] See footnote 17.

In our first series of experiments we took up the notoriously injurious steel grinding dust and the apparently harmless lime dust in order to compare the action of these dusts with that of the disputed dusts of porcelain, coal, and the closely related lampblack.

In the second series of experiments, the certainly injuriously active clay-slate (argillite) dust (high SiO_2 content) was compared with the apparently harmless cement dust and the questionable tobacco dust.

In the third series, finally, we experimented with the limestone dust present in the harmless cement, the noninjurious Thomas slag dust, and the questionable cotton textile dust.

Rabbits were used for experimental animals, after we had determined previously that experimental rabbit tuberculosis produces tuberculous lung processes, which resemble human lung tuberculosis from the standpoint of running a longer-lasting course much more than the tuberculosis that can be caused experimentally in guinea pigs.

Before beginning the dust experiments, we succeeded through a very slightly fixed infection brought about by means of inhalation of weak rabbit-virulent and human bacilli in causing an immunity-trough-disease in the experimental animals as we have done with grown, already tuberculous-diseased human beings. The secondary infection renewed later toward the close of the dusting lead to a secondary, that is, chronic indurative tuberculosis. This is a new investigative possibility which has not been used up to this time with tuberculosis experiments.

Jötten-Münster summarizes the results of these experiments as follows:

The severest changes were, as was to be expected, caused by the steel grinding dust, the next by the dusts with high silica content, such as rock dust (with clay slate), and porcelain. Of these latter, the higher the silica content the more injurious they were. Coal dust and lampblack had a moderately injurious effect, while cement, limestone, Thomas slag, textile, and tobacco dust were still less injurious, with lime dust in the form of $Ca(OH)_2$ the least harmful.

On the basis of the experiments, the disputed porcelain dust as well as the silicates can in no way be considered as harmless. Also, it is not claimed that anthracite coal dust is completely indifferent or checks tuberculosis entirely; it stands close to the zone of indifference; it even promotes tuberculosis. The tubercle has developed everywhere around the coal particles. The opinion is correct that the relative infrequency of tuberculosis among coal miners is due not to a tuberculocidal property of the coal dust but much more to the careful occupational selection, possibility of earlier disability of the miners, and other exceptional elements. The reports that the condition of other coal-dust workers, for example the men unloading the coal, does not remain for long as favorable as that of the miners indicate this.

What has been said for anthracite coal dust applies also to cement and limestone dust, which experimentally, indeed, are less injurious than coal dust but are not entirely indifferent. Results of investigations in the industry itself strengthen these views. The animals exposed for four months in the packing room to about 20 mg. dust in a cubic meter of air, in the cement mill to about 160 mg. of dust in a cubic meter of air, and those in the ball mill with about 300 mg. of dust per cubic meter of air showed the same reaction to dust and a slight promotion of tuberculosis, when infected by tubercle bacilli, as did the laboratory animals.

Our results with lime dust were especially favorable. The harmlessness of the lime may be explained principally by the fact that it dissolves in the tissue liquids and, therefore, exerts no injurious mechanical action. In addition the inhalation of lime assists the calcification of the tuberculous foci and in this way the tubercle bacilli are immobilized.

There seems to be some difference of opinion among German investigators on this subject of the effects of dust. Hollman,[19] of Solingen, makes the following deductions from his studies:

> Tuberculosis, which today in industrial regions accompanies men from the cradle to the grave, we need not regard as an occupational disease, as the course of the disease is not more severe, the fatality not higher among grinders than among other industrial workers. Infection and reinfection are decisive for its progress which depends upon exposure and the ability to withstand contagion, and these are not unfavorably affected by occupation.
>
> There is even discussion that with slight production of grinding dust the resistance to infection can be increased, that these cases run a milder course, conforming to the Arndt-Schulz law of the effect of weak irritation.
>
> There is an individual constitutional disposition toward pneumoconiosis, the preliminary conditions of which have not been satisfactorily investigated in a scientific manner. It appears in our metal grinders no more frequently comparatively than with workers in other occupations and, on the other hand, does not parallel dust production.
>
> For the prevention of pneumoconiosis as a disease limiting industry and threatening life, X-ray examinations should have place under the executives of the dusty industries, to which metal grinders belong. Such investigations, that is with good apparatus, are sufficient every two or three years.

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[19] Hollman, Schleiferkrankheit und Lungentuberkulose: Beihefte Zentralb. Gewerbeh. Unfallverhütung, No. 15, 1929, pp. 128-141.

The reduction of deaths among grinders in Solingen during the last 30 years - according to Teleky from 1923 to 1927, 40 per cent for Kronenberg and 30 per cent for Remschied - encourages us to strive for the goal by the two attainable methods of reducing this dust hazard and reducing the operation of tuberculosis infection, which brings up the most important problem of medical activity, prophylaxis.

Von Döhren[20] also mentions individual disposition toward the development of pneumoconioses. He says that whether this individual disposition is postulated by an insufficiency of the reticulo-endothelial apparatus, which is perhaps hereditary, has not yet been indisputably determined. Although some authors write that in the history of the dust-lung patients statements are found frequently regarding recovery from lung diseases, von Döhren could not confirm this observation by his material. Regarding the relations between tuberculosis and pneumoconiosis, he found that among 217 dust lungs, 6.91 per cent were associated with tuberculosis. The following figures are given regarding the frequency of pneumoconiosis among rock-drillers in the Rheinisch-Westphalic coal district: Among 11,427 miners of all occupations, 3.12 per cent were found to have pneumoconiosis, 24.4 per cent of the cases being associated with tuberculosis. The pneumocotic changes were determined among rock-drillers only, and not among purely coal-drillers, timbercutters, or truckers. Among 1,000 drillers who had worked previously in rock, 217 had dust lungs, or 21.7 per cent.

According to von Döhren, the time required for the development of pneumocotic changes is extremely varied. Observations of entirely isolated cases, in which after three to four years severe changes with or without tuberculosis were noticeable, show that very few become ill during the first five years. With increasing length of working time, however, the percentage goes up by leaps and bounds.

According to Sternberg[21] there is still a wide gulf between the findings of industrial dust lung and the results of animal experiments. No one has yet been able to produce by animal experimentation such a fibrosis as that shown by a rock-driller's lungs. He advances the following theories to explain this variation:

> The anatomical-physical difference between human lungs and animal lungs, which began as a result of the upright posture.

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[20] von Döhren, Zur Klinik der Staublunge: Beihefte Zentralb. Gewerbeh. Unfallverhütung, No. 15, 1929, 146 pp.

[21] Sternberg, M., Die Staublunge: Med. Klin., vol. 25, No. 50, December, 1929, pp. 1919-1922.

The fibrous dust lung of human beings requires several years, even ten years, for development. A similar period of time is not possible in animal experiments due to the shorter life span of experimental animals.

Schridde has found the structure of the rock-driller's nodules to be identical with the keloid of the membrance and is of the opinion that a special predisposition is necessary for the genesis of lung keloid.

The bacterial theory assumes that the genesis of a genuine fibrosis depends upon the assistance of bacterial infection of the lungs in addition to the action of the dust. This pushes to the fore the question of dust tuberculosis, which is the most frequent and the most usual bacterial infection of the lungs.

It is certain that there are cases of silicosis and indurative anthracosis, even with cavity formation, in which the most careful microscopic examination reveals not a trace of tuberculosis. Genuine lung fibrosis can develop in people without tuberculosis. However, there are regions and occupations in which practically all workers in dust who have lung fibrosis at the same time are tuberculous.

Grünewald[22] believes that the worker in the dust-producing industries seldom pays any attention to the first results of the action of dust but believes the slight cough, sneeze, and catarrh as necessary evils of his occupation or as inherited weaknesses of his family. Thus frequently from simple catarrh of the nose or throat come deep-seated changes of the lungs, such as swelling, chronic inflammation, induration, and phthisis. Grünewald states that the significance of dry dust for the origin of an infectious disease, as for example tuberculosis, is really not that of the infection carrier but of a physical and chemically active preparatory irritation for retaining the tuberculous infection. In regard to coal-dust he thinks that

> Of all dust diseases of the lungs, anthracosis is the least injurious, although at times, as a result of longer action of the coal dust, lung and air passages are distended. A special tendency of the miner's lungs toward tuberculosis is certainly to be denied. However, if the coal dust has been absorbed before breathing tubercle bacilli it is as dangerous as any other dust that contains tubercle bacilli.

Grünewald calls attention to the order of the Labor Minister of February 11, 1929, making compensable dust-lung diseases contracted in certain industries, although the order of May 12, 1925, did not include illness caused by dust.

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[22] Grünewald, Max, Die Berücksichtigung der Krankheiten der Atmungsorgane durch Staub und Gas bei der Ausdehnung der Unfallversicherung auf Gewerbliche Berufskrankheiten: Die Gasmaske, vol. 1, No. 6, December, 1929, pp. 145-148.

Russia.- Investigations on various phases of the dust hazard were conducted by the State Institute for Occupational Pathology and Industrial Hygiene of Ukraine.[23] Studies[24] on the relation between pneumoconiosis and tuberculosis consisted in experiments on animals, clinical examination of the personnel of the State Porcelain and Faience Factory, and a statistical study of mortality from tuberculosis of these workers during a 12-year period. The experimental study consisted in determining the effect of injections of colloidal solutions of SiO_2 under the skin of rabbits infected with tuberculosis and those not so infected, and dusting the animals with faience dust in order to determine the local action on the tissues. Comparison of the data obtained on the experimental animals with that on the controls showed that SiO_2 promoted the growth of the fibroblastic element so that in a series of cases tuberculous foci were incapsulated; the tuberculous process, however, progressed and showed no tendency to change a malignant course into a mild one. Similarly a causal connection between fibrosis of the lungs and the presence of a very marked destructive process was not determined. The clinical examination of the factory workers showed that the percentage of silicosis and tuberculosis was very high but the form of compensated tuberculosis predominated and only at a certain age (45 to 50 years) after a long period of work (15 to 20 years) did a "secondary wave" of exacerbation of the tuberculous process occur. This secondary exacerbation is explained by the author as due to the presence by this time of too much connective tissue in the lungs, which leads to vascular injury.

Studies carried out to determine the parthological effects[25] of sand, flint (silicon), porcelain, chamotte, anthracite, coke, charcoal gypsum, and marble dust gave the following results: Porcelain-dust, was easily hydrolized and, when introduced into the animal organism caused local necrotic lesions and toxic effect of the internal organs; with rabbits infected with tuberculosis the tuberculous process was localized in the region of "dust foci" which referred back to the necrotic action of this dust on the tissues; crystalline kinds of silicate dust (flint, sand) were not hydrolized; schamotte stood between porcelain-dust and flint and sand as far as its hydrolytic properties were concerned; coal-dust was not soluble in the organism; tissue reaction with dusts proceeded with definite activity of the machrophages; with infected animals no localization of tuberculous infection took place around the "foci" with coal-dust. Charcoal-dust showed no noticeable picture of solubility and tissue reaction; marble and gypsum dusts are hydrolyzed in the organism, and tuberculous lesions can be determined around the foci of these dusts.

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[23] Staub und Staubpathologie: Arbeiten und Materialien des Ukrainischen Staatsinstituts für Arbeitspathologie und Arbeitshygiene, Kharkov, Russia, 1930, 292 pp.

[24] Sheinin, M., Die Silicose und Tuberkulose im Lichte der klinischen und experimentellen Untersuchungen: (German summary of Russian report) Arbeiten und Materialien des Ukrainischen Staatsinstituts für Arbeitspathologie und Arbeitshygiene, Kharkov, Russia, 1930, 292 pp.

[25] Peissachovitsch, I. M., Pathologie des Staubes: Arbeiten und Materialien des Urkainischen Staatsinstituts für Arbeitspathologie und Arbeitshygiene, Kharkov, Russia, 1930, 292 pp.

South Africa.- According to the report of the Miners' Phthisis Medical Bureau,[26] 424 of the 15,492 working miners examined during the year 1928-1929 had simple silicosis. Of these 424 cases, 154 were "old" cases of silicosis, made up of miners who had previously been certified as having simple silicosis, but who had not retired from underground work. Of these, 106 were in the ante-primary, 57 in the primary, and 1 in the secondary stage of the disease; 112 were mine officials. The remaining 270 cases were "new" cases of silicosis which had originated during the year. During the year five new cases of tuberculosis with silicosis were found among the 15,492 working miners examined. All these cases occurred among unretired miners who had previously been notified as having simple silicosis. Not one was a "new Rand miner" and none had at any time passed the initial examination of the bureau. Two were "old Rand miners," one with 8 years and 11 months' and the second with 12 years and 6 months' underground service; neither had worked machine drills. Three belonged to the class "miners, Rand and elsewhere." Their average period of work in scheduled mines was 14 years and 9 months, with 7 years and 2 months elsewhere. Two had done some machine work but neither had been exclusively so engaged. Forty-four of the 15,492 miners examined were found to be suffering from "simple tuberculosis." Four of the cases, two in the "open" and two in the "closed" form, were among the "new Rand miners." The mean duration of underground service for this class prior to the contraction of tuberculosis was 6 years and 2 months; 35 of the cases, 29 "open" and 6 "closed," were among the "old Rand miners." The mean duration of the underground work of the 35 cases was 12 years. Five cases of "open" tuberculosis were found among those classes as "miners, Rand and elsewhere." The mean duration of underground work in these cases was 11 years and 9 months in scheduled mines with 10 years and 9 months' underground work elsewhere. Four had worked on machine drills but none had been exclusively so engaged.

According to the report, detailed data regarding the subsequent history of each annual group of the new cases of tuberculosis with silicosis and of simple tuberculosis detected at the periodical examinations since 1917-1918, show plainly that the liability to death bears a direct relation to the relative prominence of the tuberculous factor in each class of case. It is least in the group of originally "ante-primary" cases of simple silicosis; somewhat higher in the group of originally "primary" stage cases; higher again in the cases of "closed" tuberculosis - usually of the chronic fibroid type - which form a link between the cases of originally uncomplicated silicosis and the two classes in which an active tuberculosis is present from the outset. The two latter exhibit the highest mortality, and an early conjunction of the obvious active tuberculosis with silicosis produces a condition that is more rapidly fatal than an active simple tuberculosis alone. The association of an infective factor, and particularly of tuberculous infection, with the progressive tendency manifest in most cases even of simple silicosis has been repeatedly emphasized in these reports.

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[26] Irvine, Louis G., Report upon the Work of the Miners' Phthisis Medical Bureau for the Year Ended July 31, 1929: Government Printer, Pretoria, South Africa, 1930, 64 pp.

In regard to the position today of miners' phthisis on the Witwatersrand, Irvine and Mavrogordato[27] have the following to say:

> Although one is justified in concluding that we have turned a big corner in the matter of silicosis, it is not anticipated that the actual number of cases detected will show any significant further decrease in the immediate future. For, although the "New Rand Miners," with their relatively lower attack-rates, are becoming more numerous and the older miners fewer, nevertheless, the older miners who remain - and there are still over 5,000 of them - are every year getting older in years of service, and therefore more liable to contract silicosis. The one factor will probably for some time balance the other, and one does not therefore anticipate much, if any, actual decrease in the number of cases that will arise for a good many years to come.
>
> That is the position today. After years of hard work on the part of mining engineers and inspectors and mine officials and medical men, a large measure of success has been attained. But it is incomplete. It is satisfactory so far, but it is also disappointing. When in 1916 we found that the liberal use of water, suitably applied, would reduce the dust from drilling or blasting by 97 or 98 per cent by weight, the problem appeared to have been solved. It has only been solved so far. The trouble is that, although water will take one a large part of the way, it will not take one all the way. It has its limitations, and it has also positive disadvantages, both hygienic and economic. Hence the minds of engineers and medical men are turning today to the question: Have we not been over-doing water? Could we not do better with less water and a greater extension of alternative methods?

The matter of compensation for miners' phthisis is causing considerable concern to the industry in South Africa, as indicated by the following statements from the South African Mining and Engineering Journal:[28]

> The outstanding liabilities of the mines of the group to the Miners' Phthisis Board at 31st July, 1929, amounted to £3,150,746, as compared with £3,072,439 the year before. All mines that are in a position to do so are setting aside funds annually, so that the whole amount of their respective liabilities will have been provided during the course of their industrial lives. ***********
>
> In addition to the above, the amounts contributed out of working costs by the companies of the Group to the compensation fund of the Phthisis Board amounted in 1929 to £385,729, equal to 4s. 8d. per underground shift. If the amounts provided during the year to meet the outstanding liabilities are added to the contributions to the compensation fund, the total cost to the mines of the Group on account of miners' phthisis represents the equivalent of 6s. 10d. per shift for each white employee working underground.

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[27] Irvine, L. G., and Mavrogordato, A., Miners' Phthisis on the Witwatersrand: South African Min. and Eng. Jour., April, 1930, p. 73.

[28] South African Mining and Engineering Journal. The Cost of Miners' Phthisis: May 10, 1930, page 283.
South African Mining and Engineering Journal. Miners' Phthisis Legislation: August 2, 1930, p. 650.

The report of the latest Miners' Phthisis Commission is now due and the moment may be opportune to review the attitude of the mining industry toward this much-debated subject. That attitude has been very clearly explained by the industry in the evidence given on its behalf before the Commission. On behalf of the industry it was admitted that there should be permanent and lasting legislation on this contentious subject; but it was emphasized that to frame such legislation on retrospective lines and to provide for so-called "hard cases" is bound to produce unsatisfactory results. There are at present 35 schedules mines which are liable to contribute to the annual levy of Ł800,000 and provide for the net outstanding liability of Ł6,400,000. Several of these mines have, as yet, not been in a position to set aside annually against their outstanding liability to the Compensation Fund. Although two mines closed down during the year 1929, the Board has maintained the annual levy at Ł800,000, owing to the large outstanding liabilities of the Compensation Fund; so that these contributions have fallen with cumulative effect upon the other scheduled mines. *********

If additional benefits for miners' phthisis sufferers and their dependents, are recommended, such additional benefits should be borne by the State; in fact, it is urged by the gold producers that it would even be in the interests of the State at the present time to assist the gold mining industry in meeting some of its obligations under existing legislation. *********

Owing to the great amount of attention which has been given to miners' phthisis and the generaous scales of compensation provided, there is evidence of the growth of an idea among a section of mine workers that after they have worked a certain number of years underground, they should be provided with a pension for life, whether they be sick or sound. This is, of course, a sorry state of affairs in view of the strenuous and successful efforts made to improve conditions and the huge present outstanding liabilities placed upon the mines. It suggests the idea that a gold-mine is a bottomless purse and that one has only to ask in order to get. This attitude, one hopes, for the sake of the country as well as of the industry, will not be allowed to develop.

In August, 1930, an international conference on silicosis was held at Johannesburg, South Africa, which was attended by representatives of the principal countries interested in this industrial disease. According to a summary of the results of the conference by Hall[29] no material addition was made to pre-existing knowledge but it served a useful purpose in many ways.

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[29] United States Department of Labor, Proceedings of the Sixteenth Annual Meeting of the International Association of Industrial Accident Boards and Commissions: Bureau of Labor Statistics Bulletin 511, April, 1930, pp. 40-47.

For instance, by collecting together all the available information about dust diseases from all parts of the world, it has shown not only the number but also the position of the gaps in our knowledge of the subject, and so has given valuable indications for future lines of research. It has enabled certain standards to be agreed upon, by which future work on this subject may be comparable in whatever country or industry it is carried on. Finally, it has emphasized the urgent necessity for further experimental investigations into almost every aspect of the problem.

United States.- In April, 1929, a committee was appointed by the industrial commissioner, of New York to draft, for recommendation to the industrial board, rules relating to the regulation of rock drilling, sand blasting, and rock crushing. A report of this committee was made by Lanza[29a] at the session on occupational diseases of the Sixteenth Annual Meeting of the International Association of Industrial Accident Boards and Commissions, Buffalo, New York, October 8-11, 1929. It had been thought that the problem was that of the application of water to rock drilling, but time showed that this was not the solution as the fine dust particles came up through the water and got into the atmosphere just the same and caused silicosis as they had previously. In Manhattan it was obvious that on many of the operations - foundation work, tunneling, and subway work - especially in the wintertime water could not be used because it would form into ice and probably increase very considerably the accident hazard. Therefore, the State department of labor concentrated its attention on developing some other method of dealing with the dust problem. In its efforts, the department was assisted by the contractors, who tried to evolve some sort of a suction apparatus that would take the dust away as rapidly as it was formed at the drill hole. However, this plan proved to be not only difficult but relatively quite expensive to execute. Such a device was tested in actual operation at a subway tunnel construction. First, before any work was done the air was sampled to determine the normal dust content of the air at that place, which was found to be slightly more than 23,000 particles per cubic foot - that is, particles under 10 microns in size. Four jack hammers were then put in operation with the dust collecting device working, and the count jumped from 23,000 to 114,000 particles per cubic foot. The dust-suction apparatus was then removed and the count jumped from 114,000 to 423,900,000 per cubic foot. This was very encouraging, as the United States Public Health Service has adopted as a permissible limit 10,000,000 particles under 10 microns per cubic foot. Although it can not be said that the problem has been solved, Lanza stated they considered the most hopeful, the most promising experiment yet made. During the discussion of Lanza's report, the question was asked as to the time required to develop silicosis after exposure to silicate dust. He replied that a man working steadily in silica-dust running 99 per cent plus of silica will be seriously and usually permanently damaged at the end of five or six years; if in silica dust containing 70, 65, or 60 per cent silicate, with perhaps little better working conditions - and that is about the average in this country, with one or two notable exceptions - the time required will run to 10 to 15 years. It is a slowly developing disease and under most working conditions in this country it is a matter of 10 to 12, 14 or 15 years before a man is aware, providing he has not been medically supervised, that he is thoroughly damaged.

[29a] See footnote 29.

It was also brought out in the above discussion that in Ontario, Canada, the law provides that a man must have been exposed for five years in one of the Ontario mines before he becomes entitled to the silicosis provision. Every man is examined before he is allowed to go to work, and if he has had experience in working in silica dust and has silica on his lungs, he is refused employment. No man with a suspiciion of silicosis is allowed to go into the mines of Ontario.

The work of the U. S. Bureau of Mines Clinic, carried on at Picher, Okla., in cooperation with the Tri-State Zinc and Lead Ore Producers Association and the Metropolitan Life Insurance Co., was continued during the fiscal year 1929-30. During this period, 7,469 men were examined, of which number 3,002 were original (first annual) examinations, and 4,457 were re-examinations (second or third annual). There was a slight reduction in the number of men examined compared with the number examined last year, due to the financial depression existing in the district. A complete tabulation of the physical condition of those examined is being prepared for possible publication.

An interesting development in connection with the investigation conducted at Picher was the discovery by X-ray examination of a miliary lung disease of unknown origin[30] in 125 of the 18,285 individuals examined up to December 31, 1929. With one exception, these were all white, native Americans, the majority of whom were born and reared in the vicinity of the mining field. Most of them came from rural districts or had spent several summers in the harvest fields. A majority of these cases did not have sufficient symptoms to cause them to stop work or to seek medical aid. Many of them were men seeking employment or who had been employed underground for only a short time at most; and, apparently, mining work could not have caused the condition found. In attempting to make a diagnosis, four diseases - miliary tuberculosis, pneumoconiosis, calcium metastasis, and pneumomycosis - were considered as probable causes of the condition. However, the investigation at Picher, as well as a search of the literature, failed to reveal sufficient knowledge of this malady to warrant a statement that the cases under discussion come under one of the four probable diseases mentioned, but there is enough evidence to conclude that the disease is more prevalent than thought and for this reason is worthy of serious study.

Another dust disease, asbestosis, has assumed a prominent and perhaps peculiar interest in the field of pneumoconiosis and occupational disease.[31] Although the asbestos industry is more than 2,000 years old, it is only within the last few years that it has become so important. Until recently asbestosis was assumed to be essentially silicosis, and the free silica has been thought to constitute the dangerous factor. However, according to Lynch and Smith,[32]

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[30] Sayers, R. R., and Meriwether, F. V., Miliary Lung Disease Due to Unknown Cause: Public Health reports, vol. 45, No. 49, December 5, 1930, pp. 2994-3009.

[31] Lynch, K. M., and Smith, W. A., Asbestosis Bodies in Sputum and Lung: Jour. Am. Med. Assoc., vol. 95, No. 9, August 30, 1930, 659-661.

[32] Ibid.

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attention has been called within the last two or three years to a peculiar characteristic of asbestosis, not found in silicosis, and on which they reported data, as American medicine had thus far had no report on this peculiar condition. As mentioned above,[33] an investigation was conducted in England prior to which (February, 1928) definite knowledge existed of only two deaths of asbestos workers about whom there was expert opinion that the inhalation of asbestos-dust had at least contributed to, if not caused, the fatal outcome.[34] The second of these cases, reported by Cooke,[35] in 1924, was that of an asbestos worker who had been exposed for 20 years, the last 5 years intermittently, and who on autopsy showed extensive fibrosis of the lungs and chronic tuberculosis. A histologic study by McDonald[36] of the lung tissue of this case showed in addition certain peculiar foreign bodies in the alveoli, bronchioles, and interstitial fibrotic areas. This is the first recorded observation of these objects which since have been called "asbestosis bodies." In October, 1929, Lynch and Smith[37] found these bodies in two negroes coming to autopsy, one of whom had died of a gunshot wound and the other of lobar pneumonia. One of the men had worked in an asbestos mill for a total of 28 months during a period of about three years. The other had been working in an asbestos mill almost continuously for four and a half years. It then occurred to Lynch and Smith that these "bodies" should be found in the sputum of asbestos workers. The "asbestosis bodies" were found in the sputum of three of four patients who had been or were working in asbestos. The case in which no "asbestosis bodies" were found had worked for 14 years in an asbestos factory but not since 1926. He had advanced fibrosis of the lungs, thought to be a late stage of pneumoconiosis, without evidence of tuberculosis. The relation of the occurrence and time of duration of these bodies in the sputum to the extent of exposure to asbestos dust, and to the state or stage of asbestosis or other associated conditions in relation to their expulsion in the sputum should be given further study in the opinion of Lynch and Smith. Meriwether[38] considers the following four conditions essential for establishing a relationship between the inhalation of asbestos-dust and the development of fibrosis:

1. Work involving exposure to asbestos dust.
2. The existence, demonstrable clinically and radiologically, of a definite pulmonary fibrosis.
3. The absence of previous or present infections known to cause pulmonary fibrosis - e.g., tuberculosis, influenza, or pneumonia.
4. The absence of previous or present work involving exposure to other dusts, which might cause pulmonary fibrosis.

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[33] See footnote 12.

[34] Merewether, E. R. A., The Occurrence of Pulmonary Fibrosis and Other Pulmonary Affections in Asbestos Workers, The Jour. of Indust. Hyg., vol. 12, No. 5, May, 1930, p. 198-222.

[35] See footnote 31.

[36] Ibid.

[37] Ibid.

[38] See footnote 34.

Soper, in describing a case of asbestosis,[39] is of the opinion that the condition is more widespread than at present suspected and that just as certain other dusts took their toll over a long period before the true facts were realized, so asbestos-dust to a lesser degree appears to be taking its toll without sufficient recognition of the fact. He makes the following statements in regard to the disease:

1. A case is reported which seems to be typical of pulmonary asbestosis.
2. When there has been exposure to asbestos dust the presence of pulmonary asbestosis should always be suspected.
3. The most common single symptom is dyspnoea. This and the other symptoms are essentially those of a progressive generalized lung fibrosis.
4. The physical signs of uncomplicated pulmonary asbestosis are substantially those of generalized fibrosis of both lungs and basal pleurisy.
5. X-ray examination is of great value in establishing the diagnosis.
6. Asbestos contains but a very small amount of free silica but probably conduces to a more hasty evolution of any accompanying tuberculosis, as in the better understood forms of silicosis.
7. An immediate diagnosis at autopsy is said to be made possible by simply squeezing out upon a slide a drop of lung juice from the fibrosed tissue and covering with a cover-glass. The asbestosis bodies in large number are readily visible under the microscope.

Hatch, Drinker, and Choate[40] made a study to determine the fundamental engineering principles involved in the design of efficient dust-control systems for use with high-speed pneumatic stone-cutting tools. They summarize the results of their laboratory study as follows:

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[39] Soper, W. B., Pulmonary Asbestosis; The American Review of Tuberculosis, vol. 22, No. 6, December, 1930, pp. 571-583.

[40] Hatch, T., Drinker, P., and Choate, Sarah P., Control of the Silicosis Hazard in the Hard Rock Industries. I. A Laboratory Study of the Design of Dust Control Systems for Use with Pneumatic Granite Cutting Tools; Jour. Indust, Hygiene, vol. 12, No. 3, March, 1930, pp. 75-91.

Of the available methods of dust control, the application of local exhaust ventilation appeared to be the most promising. A study of the various granite cutting processes showed that the surfacing machine and the pneumatic hand tool alone needed investigation, since they along produced amounts of dust in excess of the standard. The heaviest dust producing tool, the four-point, was used throughout the study.

Four different hood shapes for use with the pneumatic hand tool were tested and the minimum air velocity required at the tool to keep the dust concentration at ten million particles was determined. When the hoods were operated at the minimum rates of air flow, the velocity at the tool was found to be 200 feet per minute, regardless of the size, shape, and position of the hood and the air flow through it. This value, therefore, may be regarded as a fundamental specification for hood design under laboratory conditions. For the field, it may have to be altered somewhat.

The hood shape finally adopted for use with the surfacing machine encloses the process as completely as possible. Physical barriers arrest the dust thrown away from the hood and high air velocities are created at strategic points without increasing the total air flow. The air flow requirement for the smaller surfacing machine was found to be 315 cubic feet per minute. A higher rate will be necessary when the larger machine is used.

SUMMARY OR RECENT LITERATURE ON EFFECTS ON WORKERS OF EXPOSURE TO TOXIC OR NOXIOUS GASES

Next to dust, the most important hazard to health through lack of proper ventilation is the possible presence of toxic or noxious gases in the air breathed. This hazard is present everywhere, even in the home, and is increasing with the rapid development of new chemical products. Following is a summary of some of the reports published on this subject in various industrial countries.

England.- The following table reports[41] cases of gassing for the year 1929, as compared with previous years. The figures relate to the number of cases reported, with the number of deaths in parentheses.

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[41] Bridge, T. C., Industrial Disease Among Chemical Workers: Chem. Age, vol. 23, No. 581, August 16, 1930, p. 139.

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Comparison of data on gassing, 1925 - 1929

Agent	1925	1926	1927	1928	1929
Carbon monoxide	118 (10)	101 (6)	88 (4)	81 (9)	113 (10)
(a) Blast furnace	25 (6)	9	13	22 (8)	25 (5)
(b) Power	34 (1)	32 (2)	19 (1)	20	55 (3)
(c) Coal	26 (2)	26 (1)	38 (2)	14	21 (1)
(d) Other	33 (1)	34 (3)	18 (1)	25 (1)	12 (1)
Carbon dioxide	10 (2)	4	3	8 (1)	- -
Sulphuretted hydrogen	4	3	9	9 (3)	7 (2)
Sulphur dioxide	3 (1)	2	5 (1)	10	6
Chlorine	12	13	14	17	14
Nitrous fumes	10 (2)	5 (1)	7	6 (1)	11 (2)
Ammonia	5	5 (1)	5	12 (1)	18
Benzol, benzine, naphtha and petrol	3 (1)	4 (1)	7 (2)	7 (2)	7
Other (ether, acetone, nickel carbonyl, etc.)..	35 (3)	17 (1)	23 (2)	17 (2)	36 (1)

The Senior Medical Inspector[42] calls attention to the fact that the number of carbon monoxide cases was higher in 1929 than for previous years, the reason being due to cases which have occurred at a large works where water gas is used. Accidents from carbon monoxide are often very difficult to avoid, and while the number of fatalities is not high, the possibility of many nonfatal accidents becoming so is apparent. Accidents of this class can only be avoided by the greatest care and supervision. Workers must have impressed upon them the necessity of making every use of the appliances available - breathing apparatus, rescue lines, etc. "Familiarity breeds contempt," and employers should realise that workers, in order to carry out necessary work, often take risks when they would hesitate to do so if warned fully of the dangers. There is no accident more tragic than a fatal gassing by carbon monoxide, because almost invariably one has the feeling that with foresight it could have been prevented. Unfortunately, one man overcome by carbon monoxide gas in doing some simple job, jeopardises the lives of other men who attempt rescue. It is not sufficient to have appliances for rescue or resuscitation available; the workers should be instructed in their use. Every accident of this character, even slight cases, should be carefully inquired into by every person responsible and by those who actually do the work. In such a way a better sense of the danger of ordinary jobs would be established. If the results of such an inquiry had the fullest publicity, then those engaged on similar work might be in a position to anticipate and provide against similar accidents.

The five nonfatal sulphuretted hydrogen cases were due to escape of H_2S in gasworks; three of them occurred in emptying purifiers. The two fatal cases were of an entirely different character, and affected three men engaged on the enlargement of a cesspit on factory premises. The hydrogen sulphide gas accumulated during the night and arose from the decomposition of organic matter. No tests were made before descending into the pit in the morning, and the first man to descend was immediately overcome and fell from the bucket in which he was being lowered. Brave efforts were made at rescue, and in these attempts another man also lost his life.[43]

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[42] See footnote 41.

[43] See footnote 41.

According to the British Medical Journal,[44] Sir Bernard Spilsbury, taking up the reference by Professor Haldane to the controversy as to whether carbon monoxide had any direct action upon the tissues apart from the changes in the blood, by reducing the oxygen-carrying capacity, said that it had long been known that in the more chronic forms of profound anemia very characteristic changes occurred in the body, such as an extremely fatty disease of the heart muscle and the kidneys. It was not always realized how rapidly such changes could occur in a relatively short period of anemia if the oxygen-carrying power of the blood were lowered. He had had the opportunity of investigating cases where the hemoglobin percentage had been considerably reduced for some time, and it only required a severe anemia of three or four days' duration to induce these fatty degenerations. If fairly tough organs like the liver and kidney could be so affected by anemia of that duration, certainly the brain cells must be affected, and thus the profound results of a prolonged oxygen deprivation could be accounted for. With regard to the dangers of chronic carbon monoxide poisoning to the modern community, there could be little doubt that the exhaust gases of motor vehicles would constitute a serious menace in the future. He had very little doubt that many cases of chronic CO poisoning had been overlooked in the past and present. It had occurred among workers in large garages where engines were running frequently. Unless the garages were well ventilated the possibility of CO poisoning was very present. In estimating the fatal saturations with carbon monoxide, Spilsbury said he had never obtained figures quite so high as Professor Haldane had suggested - namely, 80 per cent; he had occasionally found 75 or 76 per cent, but in most of the fatal cases he had investigated the figures were nearer 60 to 65 per cent, as an average. In very few cases had he found death occurring with a low percentage, and there could be little doubt that while a normal person required a very high percentage for a fatal dose, a person in ill health might die with a very much lower percentage in the blood. He recalled the case of a young woman who committed suicide in this way, and in her case the saturation was only 45 per cent. She had with her a child of 7, who was unconscious, but survived. The woman herself was suffering from advanced chronic tuberculosis of the lungs, and he thought the low fatal dose was occasioned by the fact that she would naturally offer less resistance than a healthy person. In two other cases, in which the percentage was about 50, one was an old and feeble person, and the other was suffering from cancer of the stomach. With regard to the recognition of carbon monoxide in the body after death, the post-mortem appearances were extremely characteristic, so that one could often diagnose a case of carbon monoxide poisoning on sight. But according to Spilsbury there was one condition that might mislead a medical man not familiar with the changes which occurred. A doctor, searching through the organs of the body, might find nothing at all to indicate the reason for death, and then be suddenly struck with the fact that the blood in the organs was bright red, so that he would jump to the conclusion that it was a case of coal gas poisoning. But that bright redness might be entirely due to the changes in the viscera after exposure to air. The blood in the viscera is of dark color when first exposed, but after exposure it becomes a bright red. One other form of poisoning in which sometimes the blood and even the viscera might have rather a bright color is cyanide poisoning. This condition is almost the only one through which a mistake in diagnosis of the cause of death is likely to be made.

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[44] British Medical Journal, Carbon Monoxide Poisoning: No. 3626, July 5, 1930, pp. 17-18.

The medical school of Leeds University[45] is studying the effects of carbon monoxide poisoning on the nervous system by experiments on birds and small animals. It has been found that, with repeated exposure to small concentrations of gas, canaries develop a tolerance that renders them unreliable for detecting concentrations below about 0.2 per cent. Lung hemorrhages were found to occur in all birds subjected to three or more exposures.

France.- The Committee of the Prefecture of Police for the Suppression of Fumes and Noxious Automobile Exhaust Gas, appointed in 1927 to study the practicability of the suppression of such fumes and gas, has published its report.[46] It considered the problem as analogous to the suppression of industrial smoke, since fumes from both sources are the product of incomplete combustion of carbonaceous materials.

Tests were made to determine the amount of carbon monoxide produced by different makes of automobiles, the effect of antiknock substances, the diffusion of CO in the air from automobile exhaust gas at various points in the city of Paris, and the effect of the gas on vegetation. The investigation showed that motors could be so constructed as to emit only a small amount of toxic gas. The results of the analyses of the air in the streets was reassuring as regards any danger to health. Certain trees were found to be particularly susceptible to dust and exhaust gas, and it was recommended that they be replaced by more resistant species. Two measures were proposed to reduce to a minimum the inconvenience from the emission from automobiles of carbon monoxide as well as other toxic or malodorant gases or fumes:

1. The imposition of regulations prohibiting automobiles, in passing through a crowd or in the vicinity of other vehicles, animals, or pedestrians, from emitting fumes or odors of a nature to inconvenience the public, impede traffic, or, referring more especially to smoke, frighten animals; special supervision of garages and of public vehicles for the protection of users from the products of combustion. This regulation would also forbid the use of tetraethyl lead and its derivatives and would fix the responsibility on the owner of the automobile or the garage, and finally on the manufacturer, for death by intoxication.

2. The personal action of manufacturers and drivers, which could be greatly facilitated through collaboration with syndical chambers of the automobile industry.

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[45] Safety in Mines Research Board, Eighth Annual Report: Colliery Guardian, vol. 141, No. 3632, August 8, 1930, p. 481.

[46] Kohn-Abrest, and Loiret, Rapport Presenté au Nom de la Commission de la Préfecture de Police pour la Suppression des Fumees et des Gaz d'Echappement Nocifs des Automobiles: Ann. d'hygiene publique, industrielle, et sociale, vol. 7, New Series, July, 1930, pp. 373-410.

Germany.- An investigation[47] was made of the toxicology and hygiene of motor traffic, because of the increasing number of accidents due to inhalation of exhaust gases from motor vehicles. The investigation included chemical analyses of exhaust gases, toxicological experiments, and practical tests as to the amount of carbon monoxide, carbon dioxide, and methane, etc., present in over 100 street blocks, tunnels, and in large garages.

The general conclusion reached - and here the authors are in striking agreement with the decision arrived at in the Final Report of the English Ethyl Petrol Committee - is that carbon monoxide is the only gas with acute action given off by water vehicles. In consequence, however, of the extraordinary rapidity of dilution, the CO concentration in the atmosphere at breathing level rarely exceeds 2 parts per 10,000, so that risk to the general public is to all intents and purposes absent. In 95 of the 101 tests the proportion of CO was under 1.5 parts per 10,000. The highest was 2.7 which, it is said, closely corresponds with observatons made by investigators in the United States. The highest proportion found by Major R. A. Hepple for the Ethyl Petrol Committee was 1.7 parts per 10,000 (at Trafalgar Square), but when the sample was taken the bottle was placed quite close to the exhaust.

As inhalation of a mixture of 2 parts CO per 10,000 parts air if continued for hours together must lead to some saturation of the blood by CO and symptoms of headache and palpitation, precautions are called for in the case of police on point duty in places where "hold-ups" are frequent, and in garages and repair workshops.

South Africa.- The ventilation of the mines of the Witwatersrand[48] has four main objects in view: the supply of air chemically pure, the mitigation and removal of the danger from siliceous dust, the supply of cool air to the deep mines, and the removal of the dust and fumes produced by blasting.

In order to meet these requirements certain regulations, promulgated under the Mines and Works Act of the Union (Handbook of the Mines and Works Act of the Union, Hortors, Ltd., Johannesburg), are applied. As regards the chemical purity of the air, carbon dioxide must not exceed 0.2 per cent, carbon monoxide 0.01 per cent, and there must be no detectable trace of oxides of nitrogen. At least 30 cubic feet of air per minute must be supplied to every person employed underground.

United States.- A review of most of the important reports of studies made on carbon monoxide, since the existence of this substance has been known, was published by the U. S. Public Health Service.[49] This summarizes the information available on the occurrence, symptoms, and diagnosis of carbon monoxide poisoning, percentages of the gas dangerous to breathe, with symptoms that occur at various percentages of blood saturation, and the pathology, prevention, and treatment of poisoning by this gas.

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47 Keeser, E., Froboese, V., Turnau, R., Gross, E., Kuss, E., Ritter, G., and Wilke, W., Toxikologie und Hygiene des Kraftfahrwesens (Auspuffgase und Benzine) (Toxicology and Hygiene of Motor Traffic.): Schriften Gewerbehyg., 1930, new ser., No. 29, pp. viii and 106. Quoted from Bull. Hygiene, vol. 5, No. 2, November, 1930, p. 898.

48 Rees, J. P., Mine Ventilation on the Rand: South African Min. and Eng. Jour., April, 1930, page 65.

49 Sayers, R. R. and Davenport, Sara J., Review of Carbon Monoxide Poisoning: Public Health Bull. 195, 1930, 97 pp.

A study was made by the Bureau of Industrial Hygiene, New York State Department of Labor[50] on the effect of chemically pure carbon monoxide, illuminating gas, and automobile exhaust gas upon the fragility of the red blood cells. When normal blood was exposed to pure carbon monoxide gas under laboratory conditions, there was no increase in the fragility of the red blood cells.

Normal blood exposed to both illuminating gas and automobile exhaust gas, under the same laboratory conditions, showed a tendency to a somewhat increased hemolysis of the red cells. The increase in hemolysis due to automobile exhaust gas is slightly less than that produced by illuminating gas.

The hemolyzing effect of these gases would seem therefore to be due to the presence of other toxic constituents rather than to their carbon monoxide content. The hemolysis produced by the several treatments outlined was not due to a change in the hydrogen ion concentration of the blood.

Carbon monoxide poisoning has been declared compensable when incurred during employment in a garage.[51]

According to Commander Brown,[52] of the Medical Corps of the U. S. Army, the disasters to the S-51 and S-4 within recent years have aroused renewed interest in the subject of methods of rescue for submarines. Among the various measures for rescue, a vital consideration is provision for the regeneration of the air in order that the crew may survive while rescue operations are being conducted. Commander Brown states the problem as follows:

> Soda lime is supplied to submarines to prevent dangerous accumulation of carbon dioxide, and oxygen is provided in the form of the compressed gas. The limitations of weight and space in submarines are such that these supplies are necessarily very restricted. As a result of careful investigation, information is now available as to the maximum absorptive efficiency of soda lime for CO_2 under the usual ventilation conditions; and the maximum time that the oxygen will last from the standpoint of survival is known for all practical purposes.
>
> There are, however, certain questions which will arise in naval circles. One of these may be formulated as follows: To what extent, if any, will the maintenance of the normal oxygen concentration minimize the effects of high carbon dioxide on men resulting from rebreathing air in submarines? Would life be materially prolonged if oxygen deficiency were prevented while carbon dioxide was accumulating to a dangerous percentage?

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[50] Mayers, M. R., Rivkin, H., and Krasnow, F., The Effect of Chemically Pure Carbon Monoxide, Illuminating Gas, and Automobile Exhaust Gas Upon the Fragility of the Red Blood Cells: Jour. Ind. Hygiene, vol. 12, No. 8, October, 1930, pp. 300.

[51] Jackson v. Euclid-Pine Inv. Co. (Mo.), 22 S. W. (2d) 849. Workmen's Compensation Acts: Carbon Monoxide Poisoning of Garage Employee Compensable. Jour. Am. Med. Assoc., vol. 95, No. 7, August 16, 1930, p. 554.

[52] Brown, E. W., The Value of High Oxygen in Preventing the Physiological Effects of Noxious Concentrations of Carbon Dioxide: U. S. Naval Bull., vol. 28, No. 3, July,1930, pp. 523-553.

Another important question is the effect of high carbon dioxide with or without oxygen deficiency on the physical and mental efficiency of men in submarines. The efficiency curve will fall, of course, when the atmosphere is vitiated by a high concentration of CO_2. It should, however, be determined, if possible, what concentraion would induce effects leading to such a loss of efficiency that the boat could not be properly operated by the personnel. It is also possible that mental efficiency may be more seriously affected than physical stamina and may occur earlier. There is apparently no record in the literature of the effect of high CO_2 on mental efficiency, although some work has been carried out in reference to physical efficiency.

An investigation was carried out to determine (1) the noxious effects of carbon dioxide with oxygen supplied to prevent deficiency and with the oxygen allowed to fall as the carbon dioxide accumulated, and (2) the influence of high carbon dioxide on physical and mental efficiency of the personnel. The investigation showed that such subjective effects as panting, dyspnea, headache, nausea, and chilliness and fatigue were somewhat less in the high oxygen group. The differences, however, were not striking, the more decided being reduction of dyspnea and less fatigue during and after the tests. The following statement is made of the effects of high carbon dioxide:

> It is felt that the personnel could carry on their usual submarine duties for a protracted period, if carbon dioxide did not exceed 5 per cent. Even at approximately 6 per cent of carbon dioxide the men could probably still carry on for a short time, the efficiency curve falling rather rapidly between 5.5 and 6 per cent. It is believed that the majority would be completely incapacitated above 6 per cent of carbon dioxide, which is regarded as the critical point. The supply of oxygen would improve physical and mental efficiency between 5 and 6 per cent of carbon dioxide but would not prolong it beyond the latter figure.

A consideration of the hazards to health and safety is an important feature in the innovation of chemicals which may have rather wide use under conditions where persons are exposed to air containing their vapors. Frequently, however, the information necessary for a basis of evaluation of the hazards is lacking, due mainly to the materials being relatively new products, or at least new to the particular field or conditions of use. In view of this, there is a continual need of research and investigations to supply the information, especially at the present time, when there is considerable activity in the development of new organic compounds of domestic and industrial importance. Fortunately, along with the activity in development, progressive chemical industries have realized the importance of the health aspects in the manufacture, marketing, and utilization of their products, and many have initiated and supported research to that end.

The U. S. Bureau of Mines,[53] in cooperation with several of the large chemical companies, has carried out an investigation of the physiological response of guinea pigs to ethylene dichloride, ethyl benzene, "cellosolve," ethylene oxide, vinyl chloride, and dioxan. From the standpoint of the health hazard, ethylene dichloride and "cellosolve" are about as harmful as gasoline, benzene, carbon tetrachloride and chloroform; ethyl benzene and vinyl chloride are slightly less harmful than these gases, and ethylene oxide is less harmful than hydrogen chloride and sulphur dioxide, but a great deal more harmful than carbon tetrachloride and chloroform. The hazard to health from breathing air contaminated with dioxan is slight. Health hazards from dioxan, ethyl benzene, ethylene oxide, ethylene dichloride and cellosolve are mitigated by the warning response manifested as eye and nose irritation. Ethylene dichloride has a distinct odor and cellosolve a disagreeable one. Vinyl chloride does not possess adequate warning properties, but gives warning by producing dizziness and disorientation in advance of harm. In the use of new substances of this kind it is always recommended that in so far as possible exposure should be reduced to a minimum, and unavoidably exposed workmen should be regularly given complete physical examination. Nearly all organic vapors are toxic and present potential health hazards, and much remains to be learned about the effects of repeated exposure to relatively small amounts.

In connection with the study[54] made on the toxic effects of materials used for mechanical refrigeration, reported last year, attention was called to the fact that the hazard to health from contamination of air by a noxious gas depends not only on the potential harmful response attending exposure, but also on the warning properties, which in effect may be termed the "accompanying warning response." This warning may be manifested as an odor, taste, irritation of the eyes, nose, or throat, or perhaps headache, vertigo, or nausea. These manifestations may be painful and even slightly harmful, but to a much lesser degree than the primary injury of exposure. The warning response mitigates hazards directly in proportion to the degree of intolerability which accompanies injurious exposure, and accordingly its absence augments hazards. This accounts for the fact that the actual health hazards from a nonodorous or nonirritating gas or vapor of comparatively low toxicity sometimes equal or exceed the hazard from a considerably more toxic substance, but one which possesses a marked odor or produces eye, nose, or throat irritation in advance of harmful exposure.

When a substance lacks the properties for giving warning, it is often possible to impart them by the addition of a small amount of another substance that has an exceedingly high warning intensity.

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[53] Acute Response of Guinea Pigs to Vapors of Some New Commercial Organic Compounds:
- I. Ethylene Dichloride
  Reprint No. 1349 from the Public Health Reports, 1930, 16 pp.
- II. Ethyl Benzene
  Reprint No. 1379 from the Public Health Reports, 1930, 10 pp.
- III. "Cellosolve" (Mono-Ethyl Ether of Ethylene Glycol)
  Reprint No. 1389 from the Public Health Reports, 1930, 8 pp.
- IV. Ethylene Oxide
  Reprint No. 1401 from the Public Health Reports, 1930, 12 pp.
- V. Vinyl Chloride
  Reprint No. 1405 from the Public Health Reports, 1930, 9 pp.
- VI. Dioxan
  Reprint No. 1407 from the Public Health Reports, 1930, 10 pp.

[54] Sayers, R.R., Yant, W.P., Thomas, B.G.H., and Berger, L.B., Physiological Response Attending Exposure to Vapors of Methyl Bromide, Methyl Chloride, Ethyl Bromide, and Ethyl Chloride, Public Health Bull. 185, 1929, 56 pp.

The manufacturers of methyl chloride and a manufacturer of refrigerating devices investigated the properties and possibilities of use of an exceedingly large number[55] of substances and selected acrolein as the most promising. These companies, after completing their investigation, asked the Bureau of Mines to make an independent study of the efficacy and suitability of acrolein. Two reports[56] were made, one for unit systems and one for multiple systems.

The studies made by the Bureau of Mines showed that exposure to 1 part of acrolein per million parts of air produces detectable eye and nose irritation in two to three minutes, moderate eye irritation with lacrimation in four minutes, and is painful and practically intolerable in five minutes. Concentrations of 5.5 parts per million of air cause painful eye and nose irritation in 20 seconds and are practically intolerable in one minute. One part per million is thought to be adequate for giving warning. When charged with methyl chloride containing 0.6 to 1.0 per cent of acrolein by volume, the amount of acrolein in the various parts of the commercial units tested was enough to give warning of leakage of liquid from the evaporator or float chamber when the concentration of methyl chloride in the air was 0.0066 to 0.01 per cent by volume, and 0.066 to 0.10 methyl chloride if the leakage was vapor from the remainder of the system. Animal experiments have indicated that repeated daily exposure of several hours to 0.005 to 0.01 per cent does not cause apparent harm and that 0.05 to 0.10 does not cause apparent harm after a single exposure of several hours.

In connection with the above studies on atmospheric contamination, attention was also given to possible contamination of food and poisoning by ingestion. Following is a summary[57] of this investigation:

The possibility of poisoning by ingestion of methyl-chloride contaminated food was studied by exposing dogs.

> No apparent signs of poisoning were caused by the average daily ingestion on four consecutive days of 500 grams of ground raw beef or 200 c. c. of milk that had been exposed 15 to 75 hours to 100 per cent methyl-chloride vapor at 35°F.

A report was also issued by the Bureau of Mines[58] on the use of ethyl mercaptan to detect leaks in natural-gas distribution systems. The bureau had been desirous of observing the practical use of ethyl mercaptan for detecting leakage of natural gas, particularly to determine whether the odor would permeate the ground and give indication of leaks in underground pipes.

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[55] Roessler & Hasslacher Chemical Co., Warning Agents for Methyl Chloride in Refrigeration Systems: 10 East 40th St., New York City, 1930, 31 pp.

[56] Yant, W. P., Schrenk, H. H., Patty, F. A., and Sayers, R. R., Acrolein as a Warning Agent for Detecting Leakage of Methyl Chloride from Refrigerators; Rept. of Investigations 3027, Bureau of Mines, 1930, 11 pp.
Schrenk, H. H., Patty, F. A., and Yant, W. P., Acrolein as a Warning Agent for Detecting Leakage of Methyl Chloride from a Multiple Refrigeration System: Rept. of Investigations 3031, Bureau of Mines, 1930, 7 pp.

[57] Yant, W. P., Shoaf, H. W., and Chornyak, J., Observations on the Possibility of Methyl Chloride Poisoning by Ingestion with Food and Water: Reprint No. 1371 from the Public Health Reports, 1930, 8 pp.

[58] Sayers, R. R., Fieldner, A. C., Yant, W. P., Leitch, R. D., and Pearce, S. J., Use of Ethyl Mercaptan to Detect Leaks in Natural-Gas Distribution Systems: Rept. of Investigations 3007, Bureau of Mines, 1930, 13 pp.

Opportunity for making these observations was recently given by E. A. Munyan, manager, gas department, Union Gas & Electric Co., who requested the bureau's cooperation in making leakage surveys of the company's distributing systems at Franklin and Middletown, Ohio.

In these leak surveys the use of ethyl mercaptan was entirely successful. It appeared to be far more efficient than ordinary inspection methods and entailed only a fraction of their cost. A discussion is given of the chemical and physiological properties of ethyl mercaptan, the procedure for conducting ethyl mercaptan surveys, the importance of favorable season and weather conditions, and the concentrations found to be effective. The odorizing of natural gas with ethyl mercaptan was found to be a practical means for detecting leakage and a much cheaper means than usual inspection methods. Concentrations of 7.7 to 9.3 pounds of ethyl mercaptan per million cubic feet of gas were found very effective in indicating house leaks. It is thought that half that amount or even less would be ample to indicate leaks of significant magnitude. Concentations of 31.0 to 46.5 pounds of ethyl mercaptan per million cubic feet of gas were found effective in indicating underground leaks in mains and service lines. The use of ethyl mercaptan caused no complaints from customers unless leaks were present.

SUMMARY OF RECENT LITERATURE ON ABNORMAL TEMPERATURES AND HUMIDITIES

The subject of the control of atmospheric conditions indoors, especially the temperature and humidity, is becoming of increasing importance in connection with the health and efficiency as well as with the comfort of the individual. An air-conditioning engineer[59] has expressed the following ideas concerning the developments that lie ahead in the "manufacture of weather":

> We are fast approaching the time when the average suburbanite will rise in the morning refreshed from sleeping in an automatically controlled and carefully regulated atmosphere. He will breakfast in a house whose temperature and humidity are conducive to good nature and sound nerves. He will tavel to the city in an air-conditioned railroad train from which objectionable odors and overheated dry air are eliminated. Upon reaching his office he will enter the invigorating atmosphere of a type of weather manufactured to suit him and lunch in comfort under the same condition.

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59 Carrier, W. H., The Future of Air Conditioning: Quoted by Floyd W. Parsons in Facts and Fancies, Gas Age-Rec., November 8, 1930, p. 770.

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> We are fast approaching the time when the average suburbanite will rise in the morning refreshed from sleeping in an automatically controlled and carefully regulated atmosphere. He will breakfast in a house whose temperature and humidity are conducive to good nature and sound nerves. He will tavel to the city in an air-conditioned railroad train from which objectionable odors and overheated dry air are eliminated. Upon reaching his office he will enter the invigorating atmosphere of a type of weather manufactured to suit him and lunch in comfort under the same condition.

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Japan.- The significance of sweating in man has been studied by Yas Kuno and his collaborators for eight years at the Physiological Laboratory of Manchuria Medical College.[60] He mentions the current view, held for many decades, that the regulation of the temperature of the body is almost the sole object of sweating, which he has long doubted since sweating may be provoked not only by an increase of temperature of the surroundings but also by emotion and mental stress. The reason for the increase in sweating due to environment is clear, but why emotion or mental stress should also cause sweating he thought should be investigated. He found that sweating caused by heating inevitably spreads over the entire body, but the palms of the hands and the soles of the feet do not conform to this general rule. However, any intense sensory stimulation seems able to provoke sweating in these parts. The most adequate cause was found to be mental stress. Mental arithmetic caused sweating on the palms of the hands and the soles of the feet. Kuno, therefore, classifies the human sweat glands in two groups with respect to causation as well as to distribution on the body surface:

> (1) The sweat glands present on the palms and the soles have the characteristic of permanent secretion and react with an increased secretion to mental or sensory stimulation but not to rise of temperature in the environment.
>
> (2) The sweat glands distributed all over the remaining parts of the body surface show little or none of this permanent secretion or "insensible perspiration." They are not responsive to moderate mental stimulation, but profuse sweating occurs from them when the temperature of the environment rises. One phenomenon is, however, common to these two different sets of sweat glands - i.e., every sweating, whenever it occurs, appears universally over its own respective district and is never confined to any single part in its area. For brevity I will designate the sweating from the former set of sweat glands as "mental or psychical sweating," and that from the latter as "thermal sweating."

He concludes that the sweat glands of human beings have three important functions: (1) The regulation of the body temperature; (2) the facilitation of physical work; and (3) the protection of the skin.

United States.- Ventilation is not air conditioning, according to Stangle and Kingsbury,[61] although a space equipped with an air conditioning system and maintaining the desired standard synthetic atmosphere is adequately ventilated. They distinguish between ventilation and air conditioning as follows:

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[60] Kuno, Yas, The Significance of Sweating in Man: Translated and published in The Lancet, vol. 1, No. 17, April 26, 1930, pp. 912-915.

[61] Stangle, W. H., and Kingsbury, H. W., Air Conditioning: IV. Ventilation-General Discussion: Heating and Ventilating, July, 1930, p. 78, August, 1930, p. 75.

Ventilation is the supply, circulation and distribution of fresh air and the accumulation, circulation and removal of vitiated air. The removal of foreign matter such as dust and dirt by means of filters may be considered as a part of ventilation but borders on conditioning of air since we are doing something to the air that changes its characteristics.

Let us, therefore, say that when we do anything to air to change its characteristics, we condition the air. Such treatment of air may be filtration, heating, washing, cooling, etc. Ventilation on the other hand, as we have stated, is the movement of, and the handling of, air in its natural state. That is why the modern phrase "synthetic atmosphere" has been coined, since it is the man-made product resulting from conditioning air.

If a space has a comfortable temperature, is free from odors, and has a gentle but definite air movement with no drafts it is well ventilated.

Supplying a certain quantity of air whether it is 2 c.f.m. per sq. ft. of floor area or 30 cu. ft. per person does not mean that the space is well ventilated. It must be comfortable.

Comfort is most important. It is Nature's way of telling us that our immediate surroundings are satisfactory for our health. If there are elements present which dull our senses this is not true. Overheating does not cause the same degree of discomfort as underheating or drafts and is not as dangerous to the health.

The American Society of Heating and Ventilating Engineers and the Bureau of Mines have made an interesting study of comfort with varying temperature, humidity, and air movement conditions. A new standard is used in defining a comfortable temperature. It is called the Effective Temperature. We base our calculations on an effective temperature of 67°, which is equivalent to 70° dry bulb and 60° wet bulb, a too high humidity. A temperature of 72° dry bulb and 57° wet bulb, which has the same effect, is to be preferred.

"In summer the temperature inside should not be lower than 10° below that outside. Comfort in summer is comparative and is varied by the amount of clothing worn and other conditions. A maximum temperature of 85° with a relative humidity of 50% is commonly assumed. This summer comfort zone will be discussed in further detail.

The effects of too dry air and the suggested air conditioning for persons suffering with respiratory diseases are described by Barnum[62] as follows:

> Dr. Herman N. Bundesen, for many years Commissioner of Health in the City of Chicago, is perhaps one of the best known of our Public Health officials who has made a real study of this subject and has written quite at length on it. He says: "Proper moisture, or what is known as humidity, is not merely desirable, but is essential to health and comfort. Humidity and temperature are in close relation and both must always be considered in connection with ventilation."
>
> Respiratory diseases are the most common of our human ailments affected by temperature and humidity. Contrary to the belief of most people, "the breathing of cold air affects the mucous membranes of the nose in such a way as to encourage the invasion of disease germs," according to Dr. J. A. Meyers, Ph.D., M.D., professor of preventive medicine and chief of chest clinic of the University of Minnesota, Minneapolis. To continue quoting Doctor Meyers: "In the treatment of the acute respiratory diseases such as coryza and bronchitis, cold air has an unfavorable effect. How often we see a patient who complains of frequent prolonged colds terminating in bronchitis which may become sub-acute. The ordinary methods of treatment have proved of no avail but, upon inquiry, we find that he is sleeping out of doors or in an extremely cold room, and will continue to have these colds until he can be convinced that he should breathe reasonably warm air with the proper humidity. With our new knowledge of the effects of the air upon the body, we are fast passing the day when pneumonia is treated in a very cold room. Better results are obtained when the air in the room is kept in the neighborhood of 63° with a humidity of 40% to 50% than when the windows and doors are thrown wide open and the patient is subjected to great exposure."
>
> Doctor Meyers holds to the same theory regarding the treatment of tuberculosis, namely that the patient is better off at a temperature of 68° F. and a relative humidity of about 40% than in the extreme cold. He speaks of the "tremendous amount of energy required on the part of the body to keep warm" and believes that this is an unnecessary tax upon the patent.

In a report of the Committee on the Atmosphere and Man of the Natural Research Council, Huntington[63] gives the following results of a study on the connection between weather and health in New York City:

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[62] Barnum, M. C., Effects of Too Dry Air: Heating and Ventilating, June, 1930, p. 83.

[63] Huntington, Ellsworth, Weather and Health: Bull. Nat. Research Council, No. 75, 1930, 161 pp.

The results here set forth agree in general with those of other investigators, but add important new features. They confirm the idea that man, like other animals, is subject to a distinct optimum of temperature. When all ages and all causes of death are combined, this optimum, as derived from the present investigation, falls at a temperature of 63° F. for day and night together. This is close to the average among the various determinations of the optimum, but one of the new things brought out by the present report is that the optimum varies greatly for different ages of life, and with respect to resistance to different diseases. Deaths from pneumonia (and influenza) decline with almost perfect regularity as the temperature rises; those of children under five years of age decline similarly but far less rapidly until the average temperature reaches 55°, but increase portentously with every rise of temperature above 60°.

Variable weather at all seasons, in New York City at least, is accompanied by a lower death rate than is uniform weather. Extremely variable weather, to be sure, is not so favorable as that which is intermediate, but it is distinctly better than that in which day after day is of the same temperature.

When temperature, humidity and variability are all combined it appears that the ideal day is one on which the average temperature is about 65° and the relative humidity nearly 90 per cent. The preceding ten days or so should have been characterized by fairly strong changes of temperature averaging 4°. These should culminate in a drop of 10 or 12°. Of course such days can not occur continually, for a further drop will carry the temperature to an unfavorable level. A rise will do likewise and will itself be unfavorable. No change of temperature will also work harm. Yet in spite of all this it is possible for days which approximate the optimum to occur frequently.

As a part of a study of respiratory illness among steel workers (pneumonia occurs with almost twice the frequency among iron and steel workers as among the employees of a group of miscellaneous industries) the U. S. Public Health Service compared the skin temperatures of workers exposed to radiant energy with the skin temperatures of workers not so exposed. Preliminary analysis of the cases occurring over a four-year period had indicated that the incidence of pneumonia was high among workers exposed to inclement weather and among those subjected to wide variation in temperature, especially extreme heat followed by exposure to much lower temperatures. The main purpose of the preliminary report[64] has been to describe the instruments employed in the field to determine radiant energy and skin temperature. Incidentally, however, a general picture of the results obtained has been given as an indication or sample of the relationship between skin temperature, radiant energy, and the atmospheric conditions among steel workers. The final comparisons have been left to a later monograph, which will show what correlations may appear between conditions found and the sickness rates, primarily pneumonia. The following points have come out rather clearly in this preliminary analysis:

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[64] Bloomfield, J.J., Ives, J.E., and Britten, R.H.: Effect of Radiant Energy on the Skin Temperatures of a Group of Steel Workers; Reprint No. 1370, Pub. Health Repts., 1930, 13 pp.

1. Intense sources of radiant energy had a pronounced effect on the skin temperatures of workers exposed to them; the forehead and cheeks showed the greatest increase.

2. Great differences in the skin temperatures of different parts of the body, for a single individual, were found in workers exposed to radiant energy.

3. Even under relatively cold atmospheric conditions, not far above the freezing point, high skin temperatures were encountered in workers exposed to radiant energy.

4. For workers not exposed to radiant energy there was a definite relation between atmospheric conditions and skin temperatures, both for arduous and for moderate work; the skin temperatures increasing with increase of effective temperature.

Tests made by Ward[65] on the measurement of skin temperature in relation to the sensation of comfort, indicate that the temperature of the skin as measured over the forehead and carotid may be used as an index of the degree of comfort of the individual. While there are undoubted individual variations, the measurements show in general that an optimum sense of comfort is experienced when the skin temperature at these points lies between 33 and 34° C. An uncomfortable sensation of warmth is reached when the skin temperature rises as high as 35 to 36°C. On the other hand, uncomfortable sensations of cold are experienced when the skin temperature falls as low as 31 or 32° C. Fewer data were obtained for this lower limit, which should be studied with more care. On the basis of these results, one might place the extremes of the comfort zone for the skin temperature of the forehead or carotid as lying between 31.5 and 35.5°C., a range of 4° C. with the optimum at 33.5° C. Beyond these limits distinct discomfort is felt. These results apply to winter conditions in a temperate climate. It would be interesting to determine whether under summer conditions or in tropical climates these limits would show an alteration in consequence of acclimatization.

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[65] Ward, Emma F., The Measurement of Skin Temperature in Its Relation to Comfort: Am. Jour. Hygiene, vol. 12, No. 1, July, 1930, pp. 130-154.